Advanced Equine Diagnostics- Magnetic Resonance Imaging

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Abstract

Magnetic resonance imaging (MRI) has become one of the most valuable pieces of diagnostic equipment in equine practice. Both standing and general anaesthetic units are available in the UK and with growing popularity and public understanding, clinicians have an increased ability to utilise this modality. Considered 'gold standard' in terms of lameness diagnostics, MRI is non-invasive and has the capacity to enable precise diagnosis and treatment to be provided. MRI does not use ionising radiation and to date there has been no conclusive evidence to suggest any negative biological hazards associated with its use in patients or technicians. Ensuring the environment the unit is kept in is regulated, with minimal outside radiofrequency interference, and a clear gauss line adhered to, MRI can be calibrated via external services electronically or manually by appropriately trained staff. Patient care and procedural understanding are crucial elements of the veterinary nurse's role, identifying possible complications and implementing nursing interventions appropriately are vital to the successful management of the equine MRI patient.

Key points

- MRI allows detailed cross-sectional imaging of the target structures using multiple planes to depict up to 500 images per hoof.
- MRI does not use ionising radiation, reducing the biological hazards associated with its use compared to that of radiography or computed tomography.
- MRI is sensitive enough to depict evidence of pre-fractural damage, hairline fractures and singular lobe ligament damage.
- Cost effective and with a multi-modal ability to identify soft tissue and osseous pathology.

Key words

- Equine diagnostics
- Veterinary Nursing
- Low-field MRI
- High-field MRI

Introduction

Lameness is one of the most common issues seen in equine practice, historically complex to diagnose, many practitioners and owners can be frustrated with the ever-eluding causation of lameness. Traditional methods of imaging can be insensitive to subtle changes in the equine patient which can cause significant discomfort. Routine nerve-blocking with local-anaesthetic and lameness assessments alone can be timely, costly, and a painstaking process which can often leave a lot unanswered. However, over the last decade magnetic resonance imaging (MRI) has become more accessible and commonly utilised in veterinary diagnostics (Mizobe *et al,* 2016; Smith, 2015a). Having been the case for years within human medicine, specialist facilities and public perception have aligned to enable practitioners the scope to advance their field and, in turn, provide outstanding quality images and accurate diagnoses; promoting animal welfare (Swagemakers *et al*, 2016). With the ability to depict bone, tendon, ligament, and other soft tissue lesions including those within the hoof capsule, MRI supersedes the accuracy and detail capability of many other imaging techniques (Dyson *et al,* 2003) (Figure 1). Within the United Kingdom (UK) the majority of equine MRI scanners are low-field standing units, with only three high-field general anaesthetic units in the country. Both modalities have opposing merit, however, the field of interest, cost and the holistic presentation of the patient play a vital role in making informed choice between the two (Biggi and Dyson, 2018). Although considered safer, there are still some patient considerations to be addressed when using the low-field scanners, long periods of sedation and a lack of food and water can lead to a higher probability of gut stasis and impaction (Bailey *et al*, 2016). Low-field scanners are often limited to the distal limb, due to the structure of the machine and movement artefacts associated with standing sedation. Although movement is alleviated via general anaesthetic in high-field, high-field scanners also have a better capacity to image the proximal limb structures, head, and cervical vertebrae of the horse. However, this is accompanied with the risk of general anaesthesia, which is widely known in horses to carry a high morbidity and mortality risk (Senior, 2013; Johnston *et al,* 1995).

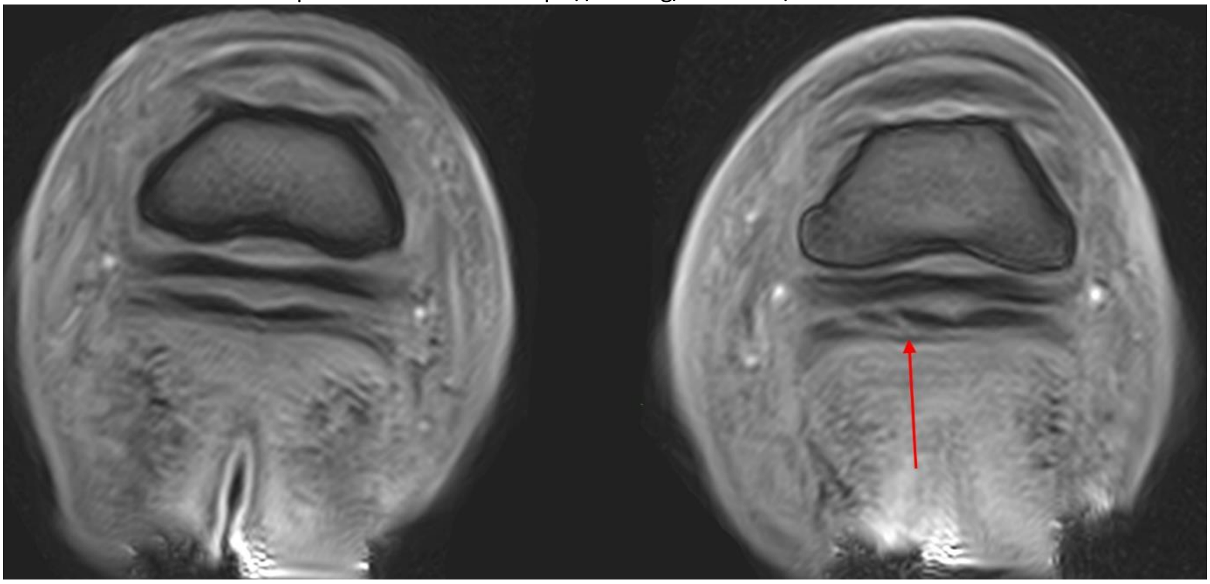

Figure 1: Parasagittal split of the deep digital flexor tendon (right), comparative limb image (left), courtesy of B&W Equine Group.

Magnetic Resonance Imaging

Unlike many other imaging tools such as radiography and computer tomography, MRI does not use ionising radiation and therefore holds no known biological hazards. Although researched extensively none have confirmed a negative association with the use of a static magnetic field (Bolas, 2010). MRI uses a combination of radio waves, strong magnetic fields, and computer technology to depict detailed images of internal structures. Considering the composition of the body (approximately 60-70% water) MRI uses the vast amount of hydrogen nuclei (protons), which are magnetic, to create the images. Once applied, the spinning protons rotate to align with the magnetic field. A radiofrequency pulse is then applied, which forces the proton out of alignment to 90° or 180° (Reddy *et al*, 2012). Following this, the radiofrequency waves are removed allowing the proton to move back into its natural position with the magnetic field (Bolas, 2010). Sensors detect the time taken for the protons to return to their original alignment whilst emitting electromagnetic energy which the computer converts into highly detailed black and white images of the structure (Formica and Silvestri, 2004). Unlike traditional imaging techniques, MRI has the ability to show both soft tissue and bone simultaneously in high resolution (Smith, 2015a; Daniel *et al*, 2011). Widely considered to be the 'gold standard' of diagnostic pathology, MRI allows detailed cross-sectional imaging of the target structures using multiple planes to depict up to 500 images per hoof, which can then be analysed by a specialist (Hallmarq, 2018) (Figure 2). Due to the sensitive nature of MRI, minor changes within the tissue are illustrated, enabling accurate prognosis to be determined and concise treatment where appropriate implemented (Werpy, 2010).

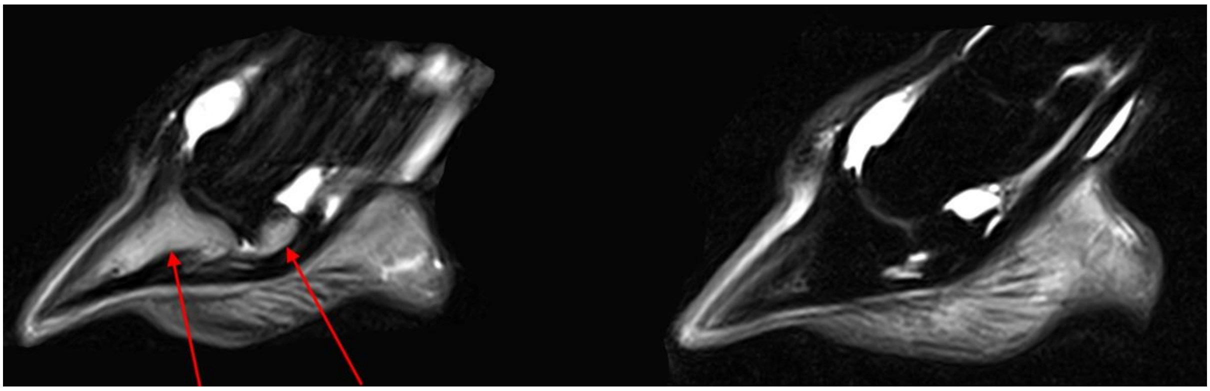

Figure 2: MRI image of bone oedema of the Pedal and Navicular bone post solar penetration (left), comparative limb image (right), courtesy of B&W Equine Group.

High-field MRI

Often tubular in shape, high-field, otherwise known as superconducting, is capable of scanning to the proximal limb, head, and cervical vertebrae, this process requires the use of liquid helium to cool the wires which aid in the creation of the magnetic field as part of the superconducting system. Turning off the superconducting magnets requires the liquid helium to be emptied from the system, which is not only expensive but also dangerous to personnel involved (Swagemaker *et al*, 2016). High field MRI scanners (>1 Tesla) have a much stronger magnetic capacity and therefore produce higher resolution images than the low-field systems. Previous studies have concluded that although for many elements of pathology both modalities have similar abilities, high-field scanners can depict lesions within the articular cartilage which would be complex to identified via low-field imaging (Daniel *et al,* 2011; Murry *et al,* 2009). Comparatively, high-field is associated with a shorter scanning time and a broader field of view, however, not without compromise, the sensitivity of the machine requires the patient to remain completely still, as even breathing can cause movement artefacts (Murrey *et al*, 2009). Therefore, patients are required to be maintained under general anaesthesia, thus increasing the risk of injury and fatalities in the horse (Senior, 2013; Johnston *et al,* 1995).

Low-field MRI

The low-field MRI scanning system (<1 Tesla typically 0.27 Tesla) has been specifically designed to image the equine distal limb under standing sedation. 'U-shaped', the system allows the patient to stand astride the magnet, scanning each limb individually (Hallmarq, 2018; Mair *et al*, 2016) (Figure 3). This design enables scanning of structures as high as the carpus and tarsus, however movement artefacts are commonly seen in areas above the fetlock due to slight swaying of the patient (Mizobe *et al,* 2016). Nonetheless, it is the lower resolution ability of the low-field that allows for this movement whilst continuing to generate high quality images (Sherlock *et al,* 2008). Allowing general anaesthesia to be avoided is an obvious advantage, both from a patient safety aspect but also a financial one. Typically, a low-field scan is considered to cost no more than a full lameness work up including nerve-block, ultrasound and radiography minus the time and hazards associated with each. In comparison, the low-field system is more cost efficient to install and maintain with a higher number of installations within practices nationwide (Mizobe *et al*, 2016; Swagemaker *et al*, 2016).

Figure 3: A horse undergoing standing MRI using Hallmarq scanner at B&W Equine Hospital, Breadstone. Photograph copyright (c) Hallmarq Veterinary Imaging 2015.

Diagnostic application

Given the anatomical composition and complexity of the equine limb it is no wonder lameness is one of the most common problems seen in practice (Donnell *et al*, 2015). It is important that prior to proceeding with MRI the general location of the lameness source has been identified, this is often via nerve-blocks and radiographs in the first instance (Smith, 2015b). By doing so, the region of interest can be narrowed, reducing scanning time and thus sedation/ general anaesthesia periods as well as mapping a concise scanning strategy (Daniel *et al*, 2011). As each patient is individual, it is common practice to image the limbs bilaterally in order to compare and identify what is anatomically normal for that patient. MRI is particularly well suited to distal limb pathology including orthopaedic and soft tissue injury (Figure 4). The proficiency to detect minute abnormalities in a structure include identifying single lobe damage within the suspensory ligament and pre-fracture pathology, which lends itself strongly to the care, training and maintenance of the competition horse (Tranquille *et al*, 2016; Daniel *et al*, 2011). This profound sensitivity allows prompt and accurate treatment to be prescribed and in turn promoting prevention or protection against further injury. Commonly, forelimb lameness is associated with damage to the fetlock and structures within the hoof, this ranges from subchondral remodelling to navicular oedema and everything in between (Biggi and Dyson, 2018). The level of detail required to identify the causes of lameness are often unobtainable by radiographs or ultrasonography alone, this can be multi-factorial but often due to poor ultrasonic access to the capsule of the hoof and inadequate clarity or reduced radiographic contrast (Mair *et al*, 2010; Blunden *et al,* 2010).

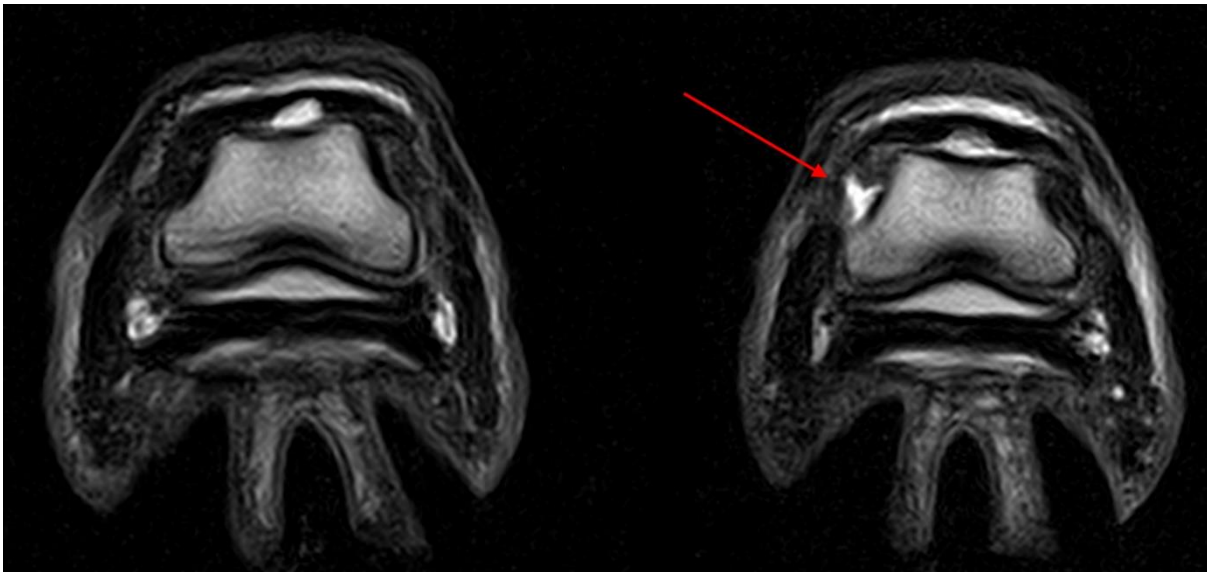

Figure 4: MRI image of collateral ligament injury of the Distal Interphalangeal Joint (right), comparative limb image (left), courtesy of B&W Equine Group.

Unit management

MRI systems need to be housed in a copper lined container or building in order to prevent outside radiofrequency interference, which can affect imaging quality and machine calibration. It is imperative the storage for the system is large enough to facilitate a protective perimeter around the magnet, known as the gauss Line (Mair *et al,* 2010). This line represents the outermost boundary of which no ferromagnetic material from either the patient or technician should pass. Although largely known, patients or technicians with metal implants or cardiac pacemakers for example are unsuitable to enter the field due to the risk of electromagnetic interference and magnetic pull of the machine causing injury (Formica and Silvestri, 2004). Metal objects within the field should always be avoided, even when not in use, as this may damage the machine. All equipment associated with the use of the MR system must be compatible with the unit, this includes anaesthetic equipment, brushes, mops, etc in order to prevent interference with calibration (Reddy *et al*, 2012). A strict hygiene protocol should be put in place between patients to not only minimalise cross contamination, but also maintain the equipment and check for damage. Although a high-field system uses liquid helium to conduct electricity and cool elements within the system, machines using 0.27 tesla or less can be regulated via environmental temperature, therefore ensuring the unit is maintained to within one degree via air conditioning and the room remains secure is imperative (Hallmarq, 2018).

Patient care

Patient compliance, behaviour and suspected region of pathology should be considered when choosing an imaging technique. Some patients, even once sedated, are not good candidates for standing MRI. An important factor in the management of the successful MRI patient is handling. Empathy and patience are vital attributes of the veterinary nurse in order to settle the patient into the situation and prevent stress; the calmer the horse the less resistance there is (Michou and Leece, 2012).

Patient preparation

General grooming should be undertaken prior to scanning to prevent any dirt, dust or bedding damaging the system. Whether under sedation or general anaesthetic, an intravenous catheter should be placed prior to the procedure for ease of venous access (Taylor *et al*, 2013). It is imperative all metal is removed from the hoof, this should include all nails and clenches and is routinely checked via radiography, even a small amount of metal in a low-field system can cause significant signal interruption (Smith, 2015a). Depending on the site of investigation, it may only be necessary to remove the hind or forelimb shoes providing they do not pass the gauss line.

General anaesthesia

Prior to general anaesthesia horses are starved for 8-12 hours, however due to their physiology and predisposition to colic it is important to monitor them for signs of gut stasis and abdominal discomfort (Nelson *et al,* 2013; Corley and Stephen, 2008). In preparation for induction patients should have their mouths rinsed out with water and their tail bandaged, this prevents food debris being pushing into the trachea during intubation and the tail interfering with positioning and recovery. It is essential all equipment to intubate, hoist the patient to the table and connections to the anaesthetic machine are organised and that all personnel understand their role in this process (King, 2014). Once in position a urinary catheter can be placed to protect the machine but also to void bladder prior to recovery. The recovery phase, whereby the patient is often inaccessible, can take 30-60 minutes ideally. A wet floor, due to urination, will increase the risk of injury as well as soiling the patient and exacerbating the possibility of hypothermia (Riley *et al,* 2016; Clark-Price, 2013). Before commencing with the scan, the veterinary nurse must ensure the patient is adequately padded and supported, this will not only reduce movement artefacts from patient breathing (if done correctly) but will also reduce the occurrence of neuropathies and myopathies (Bidwell *et al,* 2007).

Standing sedation

Once accustomed to the new environment, the sedated patient may be walked or backed into the machine depending on the views required. It is vital, once positioned, the veterinary nurse ensures the horse is comfortable in order for them to be happy to stay still for the duration of the scan (Michou and Leece, 2012). Often a head rest and chest bar can be utilised to help the patient balance, relax, and prevent excessive swaying (Figure 5). Patients are required to evenly weight bear during the scan and this can sometimes be difficult for them considering they're lame. Therefore, for patients that are deemed uncomfortable the Veterinary Surgeon may administer an abaxial sesamoid nerve block to alleviate this issue; allowing the scan to commence without interruption (Carney *et al,* 2018). In a standing unit it takes approximately 1-2 hours (depending on scanning sequences, positioning, experience, and patient compliance) to complete each limb. Patients will often require a short break to stretch out and urinate once disturbed for repositioning the second limb. However, urine output is commonly increased due to the sedation or infused sedation method chosen. With this in mind, some patients may not manage to wait till the break and ensuring the unit has a method of 'emergency' urine collection is key (Michou, and Leece, 2012). More commonly seen in geldings (but not limited to) occasional the patient will not fully empty their bladder causing multiple issues, as well as disturbing the horse and causing them to reposition themselves, there is also a risk to the unit. In these instances, it may be appropriate to pass a urinary catheter (Morgan, 2016).

Figure 5: A horse undergoing a standing MRI using a Hallmarq scanner at B&W Equine Hospital. Photograph copyright (c) Hallmarq Veterinary Imaging 2015.

Post-procedure care

Whilst the patient is still metabolising the pharmaceuticals used their temperature and mobility should be monitored, and nursing interventions completed such as bandaging the distal limbs and rugging the patient. By doing so, this protocol can reduce the instance of oedema in the limbs and hypothermia of the patient (Bennett, 2017; Riley *et al,* 2016). Both methods of scanning elicit sweating and long periods of immobility so ensuring a return to normal temperature, movement and gut motility is imperative (Morgan, 2016). Especially after general anaesthesia, it is fundamental to ensure the horse is reintroduced to food appropriately to prevent gastrointestinal impactions. During this period small amounts of soaked hard food, known commonly as 'mash', should be given repeatedly until the patient is fully conscious and ideally has passed faeces, the patient may then be provided their normal forage such as hay/ haylage. Although uncommon, in the event of prolonged gut stasis, a nasogastric tube may be passed to facilitate administration of electrolytes and fluids to promote gastrointestinal motility and hydration (Bailey *et al,* 2016; Jago *et al*, 2015).

Conclusion

Given the safety, availability, and accurate diagnosis attainable via MRI it has become one of most valuable pieces of diagnostics equipment accessible in practice. Cost effective and with a multi-modal ability to identify soft tissue and osteopathology, MRI is sensitive enough to depict evidence of pre-fractural damage, hairline fractures and direct imaging of cartilage pathology minus the ionising radiation risk to both technicians and patient. Both high and low-field scanners have their individual advantages, the choice between them should consider region of interest, cost, patient status, behavioural attribute and owner understanding of the risks associated with both.

When managing the unit, it is imperative the temperature is controlled, hygiene is maintained, and the unit is protected from external radiofrequency interference. Patient support, positioning, restraint, and recovery are vital elements underpinning the nurse's role, ensuring the patient returns to normal gut mobility and temperature. With an increased amount of public information regarding veterinary technology available and depicted in the media, attitudes towards advanced medicines are altering. Paired with access to facilities, MRI has enabled clinical advancements in equine lameness and osteopathology to be made, providing accurate diagnosis and concise treatment.

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